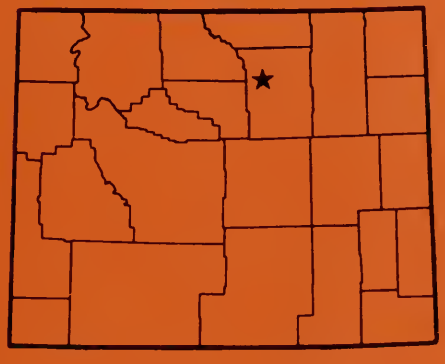
WATERSHED WORK PLAN

FOR
WATERSHED PROTECTION AND
AGRICULTURAL WATER
MANAGEMENT

WYOMING



NORTH FORK, POWDER RIVER WATERSHED

JOHNSON COUNTY, WYOMING

POWDER RIVER SOIL AND WATER CONSERVATION DISTRICT
AND
LAKE DESMET SOIL AND WATER CONSERVATION DISTRICT

1963

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WATERSHED WORK PLAN

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Johnson County, Wyoming

April, 1963

SUMMARY OF PLAN

The North Fork of the Powder River Watershed is in North Central Wyoming, near the community of Kaycee. The drainage is a sub-watershed of the Powder River Basin and contains about 193,557 acres or 302 square miles. About 66 per cent of the watershed is privately owned, 21 per cent is national reserve lands, 7 per cent state land, and 6 per cent national forest land.

The project is sponsored by the Powder River Soil and Water Conservation District and the Lake Desmet Soil and Water Conservation District. The Soil Conservation Service and the Forest Service of the U. S. Department of Agriculture, the Bureau of Land Management, and the Bureau of Sport Fisheries and Wildlife of the U. S. Department of Interior, the Wyoming Game and Fish Commission, and the Wyoming State Forester (Office of the Commissioner of Public Lands) provided technical assistance in the preparation of the work plan.

Watershed problems are a seasonal shortage of irrigation water, a need for improved irrigation water management, erosion, sedimentation, over-use of rangeland, and an infestation of Ponderosa Pine bark beetle.

This report describes the land treatment and structural measures that will be installed to provide watershed protection and agricultural water management benefits to watershed lands.

Land treatment measures will be installed on native grass rangeland, forested areas and on irrigated cropland. Measures on non-cropland will include brush and weed control, deferred grazing, roadside erosion control, forest management cultural practices, range seeding, proper range use, an insect control program and fire control intensification.

Cropland measures will consist of land leveling, new field ditches, on-farm water control structures and proper irrigation water management. Salt tolerant crops and proper tillage methods for certain soil types, as well as pasture and hayland plantings, rotation grazing, and proper pasture use are required to control erosion hazards that specific watershed soils are subject to.

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Structural measures consist of one reservoir for the storage of supplemental irrigation water. The Dull Knife Dam will be of earthen construction, seventy-nine feet high, and store 4,230 acre feet of sediment and water.

The land treatment measures will reduce erosion and sedimentation and improve vegetative cover, as well as conserve the available water supply. Improved vegetative cover conditions will tend to reduce evaporation and increase the supply of available water. The Dull Knife Reservoir will provide irrigation water for late season use on 2,807 presently-irrigated acres.

Hydrologically, the soil cover complex number will be improved from 67 to 65. Sediment delivery rates to the Dull Knife Dam will be reduced to less than one-tenth inch per square mile of drainage area during the project evaluation period. Project irrigation efficiencies will be raised from 27 to 44 per cent, and an 80 per cent chance water supply will be provided.

Project benefits are based on increased hay and pasture yields from an improved irrigation water supply. None of the commodities grown in the watershed are under production adjustment controls.

The work plan proposes a five-year period to install the complete project for watershed protection and agricultural water management. The estimated cost of installing the project is $825,880. The Public Law 566 cost will be $295,880, of which $152,360 will be construction costs on the Dull Knife Dam, $77,720 structural installation services, $21,500 to install land treatment measures on National Forest and on forested state and private lands, $8,000 for land treatment measures on National Reserve lands, and $36,300 for technical assistance in installing land treatment measures on private lands. Local or other costs for land treatment measures are $230,315 for private lands, $16,300 for National Reserve lands, and $34,130 for National Forest and forested and brush-covered, state and private lands. Local costs for the Dull Knife Dam will be $228,155 for construction, $21,100 for land easements and rights-of-way, water right, and administration of contracts. Total local and other costs will be $530,000.

Operation and maintenance will be performed by a legal entity to be organized by the North Fork Water Users Association. A revolving fund amounting to five per cent of the structure contract will be established to defray operation and maintenance costs. Annual assessments to establish the operation and maintenance fund will be about $2,520.

Average annual benefits from the installation of the project will amount to $34,260. Of these benefits, $24,185 are primary benefits accruing to irrigated lands within the watershed, $4,720 are public benefits from return flow and will accrue to irrigated lands outside the watershed, and $5,355 are secondary benefits. Average annual costs, including estimated operation and maintenance costs, will amount to $18,205. The ratio of benefits ($34,260) to costs ($18,205) is 1.9:1.

DESCRIPTION OF THE WATERSHED

Physical Data

The North Fork Watershed is in North Central Wyoming and contains about 193,557 acres. The watershed is a tributary to the Powder River and lies within parts of two major topographic provinces - the Northern High Plains subdivision of the Great Plains (Powder River Basin) and the Middle Rocky Mountains (southern end of the Big Horn Mountains). The watershed can be divided into three distinct topographic belts: (1) the Big Horn Mountains, (2) the mountain flank and foothills, and (3) the lower valley, a broad drainage with hogbacks, cuestas, and plains.

The North Fork of Powder River heads in the Big Horn Mountains at an elevation of approximately 9,400 feet. It flows southeastward along the top of the Big Horn Range in a narrow, constricted channel. The gradient changes abruptly along the east flank of the mountain which is formed by the dip slope of the Tensleep sandstone and rocks of Permian age. Here the stream has eroded a very steep sided youthful canyon as much as 400 feet into the mountain flank. Rapids and overfalls are common. As the stream leaves the mountain and enters the Powder River Basin, it flows with a progressively decreasing gradient, becoming sluggish and sediment laden where it flows into the Middle Fork, about 4 miles east of Kaycee, Wyoming.

The flood plain of the North Fork of Powder River varies from a quarter of a mile to a mile in width through the foothills and lower valley. Three thousand, three hundred acres of irrigated land lie along the flood plain. Eighteen separate canals, each with its own diversion, distribute water for irrigation. The areas irrigated by a single canal system vary from 32 to 494 acres. The crops grown are small grain, improved pasture grass, and alfalfa for hay.

In the lower watershed, the average annual precipitation of about 10 inches results in a semi-arid climate. The upper watershed is mountainous with cool days and nights. Although afternoon showers are a daily occurrence during the summer and the annual precipitation is more than 20 inches, the relative humidity is low. Annual precipitation varies from about ten inches in the lower watershed to more than twenty inches on top of the Big Horn Mountains. The growing season is from May 9 to September 26, a period of 140 days.

Local rains of cloudburst intensity characterize summer storms along the flanks of the mountain and the lower reaches of the watershed. The normal storms at higher elevations are light showers and occasional, two-day intermittent rains. Winters are cold with frequent blizzards. Chinook winds with accompanying snowmelt are a common occurrence.

The upper part of the watershed consists of steeply sloping, mountainous terrain broken by narrow stream valleys and high parks. The valley soils are moderately sloping, deep to moderately deep, very dark colored loams, silt loams, and sandy loams, that are often subjected to wetness adjacent to streams. The high parks consist of moderately-steep slopes with shallow to moderately deep, moderately coarse and medium textured dark colored soils overlying limestones and sandstones. The steeply-sloping mountain areas are made up of shallow to very shallow, medium to coarse-textured soils, with exposures of granite and limestone. Much of this area is forested.

Many geological formations are found in the mountain flank and foothills which consist of gently sloping parks, steep-timbered hillsides, vertical-walled canyons, and moderately sloping long mountain flanks. The sloping parks consist of medium depth, moderately-fine to moderately-coarse textured, dark colored soils developed on limestones and sandstones. The steep-timbered hillsides are composed of shallow to very shallow, medium to moderately-coarse textured soils derived from limestone and sandstone. The steep canyons are predominantly barren limestone and sandstone, with large boulders, cliff fall and wastes. The mountain flanks are dissected by deep canyons leading through the foothills section of the watershed.

The lower valley area consists of high outwash terraces, and rolling to steeply-sloping uplands. The terraces are of medium depth to deep, medium to fine textured, moderately dark colored soils. (Big Horn and Wolf Series). The uplands range in slope from 8 to 30 per cent and consist of shallow to moderately deep, fine to medium textured, light to moderately dark colored soils derived primarily from shales (Lismas, Midway, Molt, Bascomb Series). The river valley is made up of moderately sloping, fine textured fans at the base of the uplands, and nearly level, medium, moderately coarse and fine textured alluvial soils in the flood plain.

Areas of wetness, some of which are saline, occur in the fan and alluvial soils. (Havre, Glendive, Lohmiller, Marias, Shorey, and Vananda Series.)

Economic Data

Ranching and livestock farming are the main agricultural enterprises in the watershed. The principal sources of cash income are from cattle, sheep, and wool.

There are twenty-three farm and ranch units in the watershed. Fourteen operating units have irrigated land and receive water by direct diversion from the North Fork of the Powder River. Thirteen of these units need storage to provide a supplemental water supply. Nine ranch units have no irrigated lands within the watershed.

Nine operating units that will use stored water are cooperating with the Powder River Soil and Water Conservation District. Six of these have basic soil conservation plans. All operating units are owner-operated.

The average size operating unit participating in the agricultural water management phase of the project has 8,141 acres of rangeland and 236 acres of irrigated land. Irrigated lands serve as a base for livestock operations. Hay raised on irrigated land provides a winter feed base for livestock operations.

Present crop distribution on irrigated lands is 78 per cent tame hay, 5 per cent native hay, 8 per cent oats, 8 per cent irrigated pasture, and 1 per cent miscellaneous crops.

Summer and fall range is on private rangeland and public lands under range use permits. Bureau of Land Management and Forest Service permits are tied directly to the basic farm and ranch unit.

The present market value of land in the watershed ranges from $20 to $40 per acre for rangeland and from $180 to $225 per acre for irrigated land.

Land use and ownership in the watershed is as follows:

Land Ownership		Land Use	
Forest Service	10,808	Woodland	26,216
Bureau of Land Management	41,217	Range	163,063
State	13,140	Irrigated Cropland	3,300
Private	128,392	Other	978
Total	193,557	Total	193,557

U. S. Highway 87 extends north from Kaycee through the watershed. State Secondary 1002 crosses the lower end of the watershed and State Secondary 1001 extends west from Kaycee to Mayoworth. These highways and county and township roads adequately serve all farm and ranch units in the watershed. Local transportation needs are supplied by independent truck and bus lines.

Cattle and sheep are commonly marketed at Denver, Colorado, and at the Worland and Torrington sales barns in Wyoming.

Kaycee, with a population of 284, is near the lower end of the watershed. Buffalo, 47 miles north of Kaycee, and Casper, 78 miles south of Kaycee, serve as the trading centers for the watershed. The rural population of the watershed is 102.

WATERSHED PROBLEMS

Floodwater Damage

Floodwater damages on the North Fork of the Powder River are minor. Flooding that has occurred on the main stem has been associated with spring snowmelt and limited to bottomland pastures. High intensity summer storms of short duration (20 minutes) move across the lower watershed. These fast-moving, cloudburst-type storms affect relatively small areas. Surface runoff from this type of storm is rapid; causing erosion and sedimentation. However, there is very little inundation of cropland and damages occur primarily on low value rangeland and are not monetarily significant.

Erosion Damage

There is active sheet and gully erosion in the lower part of the watershed. Active erosion occurs in small tributary drainages along the North Fork. Numerous small gullies and rill areas can be seen. The gullies are from 3 feet wide and 3 feet deep to 25 feet wide and 20 feet deep. Many of the gullies have vertical head cuts. The erosion occurs on low value range lands that will not economically justify structural works of improvement. However, land treatment measures are effective and will be used in parts of the watershed to reduce erosion damages.

Sediment Damage

The upper watershed is located in the southern portion of the Big Horn Mountains. It consists largely of bare rock exposures with thin soils, forested valleys, and grassed park areas. Sediment production is low.

The lower watershed, in contrast, is highly erosive. Geologic formations in the foothill and plains area are principally shales and weak sandstones. Considerable amounts of gypsum occur and the derived soils are erosive and highly dispersed. Sediment rates are high, and large amounts of recent sediment are deposited on fan areas and along the flood plain of the North Fork of Powder River. These sediments are predominantly clays, clay loams, and silts which are relatively fertile. Decrease in productivity in these areas is small. Some damage, however, occurs to irrigation facilities and on newly seeded stands of tame hay.

Water Management

A shortage of irrigation water in July and August is the primary watershed problem. Annual water yield fluctuates widely from year to year. Recorded flows at the Dull Knife Dam site for the period 1947-1960 vary from 5,180 acre feet to 14,127 acre feet. Spring snowmelt provides the majority of stream flow. As a result, almost 69 per cent of the annual yield at the dam site occurs during the two months of May and June. At the Mayoworth station in the lower watershed, average stream flows of 86 c.f.s. during May drop off to 17 c.f.s. in August. Sections of the stream are completely dry and water is not available for livestock during parts of August and September. These conditions create a severe water shortage that occurs annually. Fluctuations in water supply have limited the irrigated acres that can be depended upon to produce a crop. The excess of water during May and June results in the wild flooding of as many acres as possible when water is available. Attempt- to utilize spring flows as they occur is poor water management. Surface runoff rates are high and over-irrigation is common. Field irrigation efficiencies during this period drop to about 20 per cent. The water supply is not firm enough to justify the physical measures needed for improved water management. The basic resources of land and water are being wasted and the economic development of the watershed is severely limited.

PROJECTS OF OTHER AGENCIES

The Bureau of Reclamation

The Bureau of Reclamation as a result of Senate Document 191, 78th Congress, has prepared a preliminary report on the Powder Division of the Missouri River Basin. The North Fork of Powder is treated as a part of the Crazy Woman Unit in the report. No Bureau of Reclamation works exist or are being planned in the Crazy Woman Unit at present.

The preliminary Powder Division report proposed the development of supplemental storage at a site one-half mile downstream from the present site. The report also proposed diversion of excess flows into the Crazy Woman drainage.

The availability of flows excess to the needs of the North Fork of Powder will not be affected by construction of the Dull Knife Dam. A feasible plan providing for future development of water resources can be formulated by either replacing Dull Knife storage with storage at the Hat Ranch, or enlarging the capacity of the Prospector Site, within the Crazy Woman drainage, to provide for additional carry-over storage.

Other proposals in the Powder Division include the Hole in the Wall Dam and the Moorhead Dam. Local interest in these works has increased recently and further studies are presently being made. The North Fork of Powder River Watershed Project will provide some additional late season flows for irrigated acres at Sussex and reduce the need for supplemental irrigation water from the proposed Hole in the Wall Reservoir. The watershed project is not expected to have any significant effect on main stem storage at the proposed Moorhead Dam.

Bureau of Land Management

Johnson County, which contains more than 90 per cent of the watershed area, has been designated as a depressed county, and will participate in the Accelerated Public Works Program.

The Bureau of Land Management expects to receive an allotment of such funds and has proposed that additional on-site watershed protection measures be installed within the watershed. These on-site measures include sediment control dams, gully plugs, timber thinning, fencing, and other non-project type developments. Watershed protection measures proposed by this watershed work plan will supplement the measures which the Bureau of Land Management expects to install under the Accelerated Public Works Program.

Proposed project type works of improvement will consist of an access road along the north side of the North Fork of Powder River, an access road to a picnic and recreation area upstream from the Dull Knife Dam, and the development of the picnic and recreation area. The access road along the north side of Powder River will increase the accessability of the Dull Knife Dam for operation and maintenance. Installation of the access road and recreation area will assure the realization of incidental recreation benefits at the dam.

BASIS FOR PROJECT FORMULATION

General

Land and water are the major natural resources of the North Fork of Powder River Watershed. Minerals, timber, scenic and recreational attractions are other watershed resources, but resource development has been largely confined to the use of land and water for agriculture. Watershed development started from large ranch operations based on free range passed through homesteading and dry farming stages to the present well stabilized livestock operation based on hay production from irrigated cropland.

Irrigation has developed through private enterprise and initiative with the investment of private capital. The simple and more apparent diversion sites have been utilized, natural stream flows are over-appropriated, and further development must involve construction costs beyond the financial ability of private operators.

Watershed Problems

Annual water supplies fluctuate through a wide range. During periods of record the flow of North Fork has varied from 5,000 to 19,000 acre feet at Mayoworth. Poor distribution of flow is also a contributing problem. A typical hydrograph of annual flow has a period of low flow through the fall and winter months, a rise and decline in March from low elevation snowmelt, another sharp rise in May from rains and high elevation snowmelt, a rapid drop in June, and a slower drop in July that continues through August and September. This fluctuating water supply results in poor water management, low irrigation efficiencies and is a detriment to irrigation system improvement.

The watershed above the Dull Knife Dam produces almost all of the water available for agriculture. The economy of the watershed hinges on the ability of the upper watershed to continue to produce water of good quality and in enough quantity to support the present level of irrigation development. At the present time, the hydrologic cover conditions are considered good.

Problems in the upper watershed are associated with maintaining water quality, lengthening the period of snowmelt runoff, and increasing the production of useable water.

The lower watershed, consisting of the mountain flank, the foothills and the lower valley, is a range resource area. Range conditions vary from poor to excellent with most of the range being in fair condition. The majority of the ranges that have

adequate water and are accessible are in an over-used condition by the end of the grazing season. Over-use results from attempting to extend the grazing season to conserve winter feed and reduce the amount of hay that has to be purchased.

The shale and soft sandstone formations that are exposed are highly erosive. Sheet and gully erosion is active in tributary drainages.

Watershed protection problems in the lower watershed are the improvement of vegetative cover conditions and the reduction of erosion and sedimentation.

Project Objectives

The objectives of the project are to maintain and improve the basic resources of land and water by providing an adequate level of watershed protection and agricultural water management. These objectives will be met by applying a land treatment and structural program within a five-year installation period.

Problem Solutions

The water supply problem will be solved by increasing irrigation efficiencies and by providing storage to supply late season water.

Increased field efficiencies through proper irrigation water management will conserve the available water supply more than any other measure. Proper water management will include the measures needed to control water as well as the application of water at the time, rate, and in the amounts needed. To achieve the field efficiencies on which storage needs are based, a large amount of technical assistance will be needed. Technicians will need to work with individual irrigators to acquaint them with the moisture-holding capacity of specific soils, recommended rates of application, time of set, and other phases of irrigation water management. New irrigation systems, land leveling, drops, checks, turnouts, etc. will need to be designed and installed on each field. To accomplish this within the five-year installation period will require accelerated technical assistance.

Conservation of the existing water supply by improvements in systems and management will not prevent substantial water shortages in July and August. Supplemental storage will be provided for late season use. Storage needs are based on an operational study covering the water years 1932-1961. The irrigation demand for each irrigated acre assumes that the efficiencies established by the "Irrigation Guide For Eastern Wyoming", will be achieved.

Land treatment measures for watershed protection in the upper watershed are designed to maintain water quality by treating specific erosion areas. Improvement of vegetative cover conditions will result in higher soil intake rates and lengthened stream flow from ground water. Forest management cultural practices and the conversion of brush to grass vegetation will increase the production of useable water by decreasing evaporation/transpiration.

The development of an adequate water supply and increased forage production from the irrigated lands will have a major effect on watershed protection problems in the lower watershed. The increased forage will allow ranchers to shorten their grazing season and facilitate proper range use. Deferred grazing, range seeding, and brush control will also be used to improve vegetative conditions and reduce erosion and sedimentation.

Level of Development

With the project installed, project irrigation efficiencies will be raised from their present 27 per cent to 44 per cent. Field irrigation efficiencies will be raised to 59 per cent, farm ditch efficiencies to 90 per cent, and canal and diversion efficiencies to 83 per cent. These compare to present efficiencies of 40 per cent field, 85 per cent farm ditch, and 80 per cent canal and diversion.

Four thousand, two hundred and thirty acre feet of supplemental irrigation and sediment storage will be provided by the Dull Knife Dam.

The combination of increased irrigation efficiencies and supplemental storage will provide an eighty per cent chance water supply for 2,807 participating acres.

When project irrigation efficiencies are reached, the needed water supply will be available 80 years out of 100. Varying shortages will be experienced during the remaining 20 years.

Economic Considerations

Ranches in the watershed have evolved over a long period of time into stable economic operating units. The majority of the irrgated lands are in Capability Classes II and III and capable of producing high yields of hay and grain. The fundamental need of the area is an expanded feed base, obtainable only through a stabilized irrigation water supply. Project repayment costs are estimated at $3.41 per acre per year for 2,807 participating acres. These costs are well within the repayment ability of project lands.

Project justification is based entirely on agricultural water management benefits. Average annual benefits from agricultural water management and secondary benefits are shown in Table 6 of the work plan. Recreation or redevelopment benefits have not been used.

WORKS OF IMPROVEMENT TO BE INSTALLED

Land Treatment Measures

Land treatment measures were the first consideration in developing this watershed work plan. Only those land treatment measures which will contribute to the purposes of the project and can be installed during the project installation period are included. The proposed land treatment measures have a direct effect on structural design criteria and are in effect the bases for determining structural needs.

Watershed protection is vital to the successful operation of the project. With adequate protection of watershed lands above the reservoir, the design life of the sediment pool will be assured. This will result in the design capacity of the reservoir pool being available for the seventy-five-year evaluation period. Unless an intensive, accelerated land treatment program is installed on the irrigated acres, there will be a chronic water shortage. A non-profitable project would result. The importance of the land treatment program to the realization of project benefits cannot be overemphasized.

A. Private Lands

Private lands include native grass rangeland, private forest land, and irrigated cropland. Water from rangeland flows across canals and laterals within the project. Reduction of sediment delivery rates and surface runoff by increasing vegetative cover will have a significant effect on distribution system maintenance costs. Watershed protection measures most needed on the native grass rangeland are as follows:

Proper range use is the most effective means of increasing vegetative cover and will be achieved on 48,800 acres of rangeland by the end of the project installation period. Proper utilization and distribution on the existing acres will be needed.

Distribution of livestock will require the development of stockwater. Sixteen wells, 25 spring developments, 7,920 feet of pipeline, and 50 farm ponds will be installed to achieve proper livestock distribution and help obtain proper range use.

Nineteen thousand six hundred acres of rangeland have been classified as having an undesirable density of weed and brush vegetative cover. Brush and weed control, accompanied by range deferred grazing will be carried out on five thousand of these acres. Two hundred acres of range seeding will be done by planting adapted grasses where precipitation and soils will assure good results. Range deferred grazing will be established on 15,500 acres. Large increases in vegetative cover can be accomplished by diverting runoff from natural channels and spreading it across relatively flat areas of rangeland. Waterspreading will be installed on two areas totalling 50 acres.

Irrigation water management is the land treatment measure most directly affecting project benefits. A management practice requiring the complete control of water, this measure is dependent upon having the physical means to control water as well as following recommended procedures. Irrigation water management will be achieved on 724 acres by the end of the five-year project installation period. Measures to insure irrigation water management include 600 acres of land leveling, 67,000 linear feet of field ditches, and 120 structures for water control. The rehabilitation of 18,000 feet of irrigation canals in 8 distribution systems will provide the capacity to deliver irrigation water needs during the period of peak consumptive use. Three cropland areas containing 120 acres adjacent to the North Fork of the Powder River are in need of subsurface drainage. Five thousand linear feet of drainage, main or lateral, will be constructed to insure that excessive ground water will not depress yields. Hayland planting (1,500 acres) is a part of conservation crop rotation. This amount of hayland planting will be performed during the project installation period. Pasture planting, rotation grazing, and proper pasture use will be installed on 260 irrigated acres. Land treatment measures on irrigated cropland have a direct effect on both the use of irrigation water and project returns.

B. Bureau of Land Management

There are about 1,845 acres of National Land Reserve above the Dull Knife Dam site consisting of forested and grass rangeland and used for grazing these lands are in good hydrologic condition. No land treatment measures are recommended for National Reserve Lands above the Dull Knife Dam.

Runoff and erosion from National Reserve Lands in the lower watershed have a direct effect on operation and maintenance costs of canal systems and the maintenance of irrigation improvements. Research studies conducted by the University of Wyoming show significant reductions in both surface runoff and erosion from brush and weed control. Three areas totalling 1,000 acres of dense sagebrush are adjacent to distribution canals and will be chemically treated to control sagebrush. This practice, and intensive management, will improve the hydrologic quantity and quality of cover and reduce the amount of sediment deposited in canals and carried onto cultivated lands.

There are 150 acres in the lower part of the watershed which are considered an erosion hazard to the cultivated fields lying immediately below them. Contour furrowing and seeding to an adapted forage specie will be applied.

Ten check dams will be constructed to reduce the rates of channel discharge, check active head-cuts, and control sedimentation. The check dams are small structures placed in channels which drain areas on which sagebrush control will be applied. Designed for a ten-year life, their purpose is to provide protection while vegetative cover is being established.

The forest on National Reserve lands is infested with Black Hills Beetles. A treatment program providing for the removal of infested trees, about 1,500, will be carried out.

Technical assistance will consist of condition and trend surveys, developing management plans, installation of watershed protection measures, and supervision. The present level of fire protection on National Reserve Lands is considered adequate. Existing protection measures include a fire cache at Kaycee, a trailer camp and fire cache at Mayoworth, and per diem guards at Kaycee and Buffalo.

Land treatment costs from Public Law 566 funds and other funds for National Reserve Lands are shown in Table 1 of the work plan.

C. Forest Service

National Forest lands are all above the Dull Knife Dam. Land treatment measures on National Forest lands are those measures needed immediately to improve vegetative cover, retard runoff, and reduce erosion.

Treatment measures to be installed during the five-year installation period consist of spraying forbs and sagebrush (856 acres), fence construction (7 miles), drainage of secondary and abandoned roads (14 miles) drainage of primary roads (20 culverts), fire hazard reduction (56 acres).

Sagebrush and forb spraying are limited to areas of grazing disturbance. Past over-use has resulted in large patches of sagebrush and lupine. Without accelerated treatment, recovery of these areas to climax vegetation would be extremely slow.

Fence construction is needed to eliminate areas of dual use, to obtain pasture units for rotation grazing, and protect sprayed areas until vegetative recovery is complete. The objective is to increase the ground cover vegetative density in specific areas.

Drainage of secondary and abandoned roads, as well as existing primary roads, will control the most concentrated sediment source from Nation Forest lands. Under present conditions, roads serve as channels to collect surface runoff. With drainage, surface runoff will be dispersed and sediment delivery rates from this source sharply reduced.

The fire hazard abatement zone is the main haul road to the existing timber sale area. Abatement will consist of removing heavy downfall for a distance of one-half chain on each side of the road. Burned areas above the reservoir would be a critical hazard to the life of the reservoir. No additional or accelerated technical assistance will be needed to install these measures on National Forest lands.

D. State and Private, Forest and Brush-Covered Lands

An estimated 5,738 acres of state and privately-owned forest and brush-covered lands are within the watershed. Watershed treatment needs for these lands have been developed by the State Forester (Office of the Commissioner of Public Lands).

The land treatment program on these lands consists of fire control intensification and forest management cultural practices to obtain hydrologic benefits.

Properly spaced, fast growing, healthy stands of timber result in increased resistance to losses by fire, insects, and disease. Reducing these losses will result in direct long-term hydrologic benefits. Installing management measures will increase yields and produce higher quality wood products. Higher quality wood products and increased yields will discourage changes to other land uses of less hydrologic benefit.

Approximately sixteen management plans will be developed. Two of these will be detailed plans outlining and scheduling specific management proposals for improving hydrologic forest conditions. All of the plans will outline basic treatment including protection from fire, grazing, and overcutting.

Fire control intensification measures will consist of installing two fire caches to protect areas above storage and two stream fords to improve access for fire control. Accelerated technical assistance will be required for the development of timber management plans, locating and supervising the construction of stream fords, obtaining and installing fire aches, developing a fire plan and giving stepped-up training to a fire warden. The technical assistance will be furnished by the State Forester through a cooperative agreement with the U. S. Forest Service.

Structural Measures

Structural measures needed for the North Fork of the Powder River Watershed consist of one reservoir providing supplemental irrigation water.

The reservoir is on the main stem of the North Fork of Powder River in Sections 21, 22, and 27; Township 47, North, Range 85 West. Maximum storage capacity at the crest of the combination emergency and principal spillway (elevation 8,145) is 4,230 acre feet. The reservoir pool at this stage will be about one mile long, one-quarter mile wide, and contain 130 surface acres. The elevation of the bottom of the reservoir is 8,072. The maximum pool depth is 73 feet. At maximum pool depth, the reservoir will contain 4,095 acre feet of water for irrigation purposes and 135 acre feet allocated to sediment storage. No storage is allocated to flood prevention or recreation as a specific purpose.

The dam will be an earthen embankment about 600 feet long. The maximum dam height will be 79 feet. The top width will be 24 feet and about 263,760 cubic yards of fill will be needed. A reinforced concrete conduit 2'x3' and about 460 feet long, will be constructed to provide for the release of irrigation water. A manually-operated gate will control flows through the conduit. The maximum release for irrigation use will be 90 cubic feet per second. A minimum flow of two and one-half cubic feet per second will be maintained immediately below the reservoir to insure a live stream for fishery management.

There is a low swale south of the dam which is below the proposed high waterline. A dike 600 feet long and 20 feet high with 12 feet of top width will be constructed across this swale.

A combination principal and emergency spillway 40 feet wide will be constructed in the right hand or south abutment of the dam. Excavated through solid granite, the spillway channel will drop sharply from the crest. Erosive materials along the sides of the spillway will be rip-rapped with an average depth of 7.5 feet of granite rip-rap. A downstream channel will be constructed to carry spillway flows and reservoir releases. Six feet of freeboard will be available between the crest of the spillway and the top of the dam. Based on stream gage data, a two-year frequency flow will have a peak discharge of 240 cubic feet per second. The fifty-year frequency will be about 520 cubic feet per second. The freeboard inflow hydrograph has a peak flow of 2,610 cubic feet per second. Routing this flow through the structure with the reservoir full, a maximum spillway flow depth of 4.1 feet will be reached, and the spillway discharge will be 860 cubic feet per second.

An existing county road crosses the reservoir pool area. Four thousand eight hundred linear feet of road relocation will be required as well as a new county bridge. The county road will be 20 feet wide and have a 66 foot right-of-way. A timber bridge 16 feet wide with 24 feet of clear span will be placed across the channel of the North Fork of Powder River.

A water right application for the storage of 16,000 acre feet of supplemental irrigation water was filed with the State Engineer's Office in 1959 by the North Fork Water Users Association. The State Engineer's Office has assured the sponsors that this application will be approved for 4,230 acre feet of storage upon receipt of detailed plans. The date of priority will be that of the original application. Figure 2 of this work plan shows an artist's conception of the Dull Knife Dam. Figure 3 presents structural details, and Figure 4 (Project map) shows the location of structural measures.

Table 1 contains a tabulation of structural costs. Table 2 consists of estimated structural costs and their distribution between Public Law 566 and other funds. Drainage area, storage capacity, spillway data, height of dam, and other structural details will be found in table 3.

EXPLANATION OF INSTALLATION COSTS

The estimated project installation cost is $825,880. Included are land treatment costs of $346,545, structural costs of $380,515, installation services of $77,720, and other costs of $21,100.

Land Treatment

Land treatment measures for watershed protection will be installed on private, state, and federal lands. Costs shown under "Soil Conservation Service" in Table 1, ($266,615) are for the installation of measures on private lands and for accelerated technical assistance. Average costs as determined by records of the Agricultural Conservation Program in Johnson County were used to estimate the cost of installed measures. The installed cost ($223,255) includes cost-sharing available under other programs. Public Law 566, accelerated technical assistance costs of $36,300 are for the time, travel, and overhead of Soil Conservation Service personnel in making soil surveys, revising conservation plans, laying out practices, and supervising the installation of land treatment measures. The remaining $7,060 is the "going" program of technical assistance provided by the Soil Conservation Service.

The cost of needed land treatment measures on National Reserve lands will be $24,300. Public Law 566 funds will provide $8,000 and Bureau of Land Management funds will provide $16,300. Public Law 566 funds will be used to reduce surface runoff from uplands that presently affect irrigated lands. Bureau of Land Management costs are for condition and trend surveys, range management plans, Black Hills beetle control, and the technical assistance needed to design and install the protection measures that Public Law 566 funds will be used for.

The land treatment program of the Forest Service, U. S. D. A., for watershed protection, includes work on state and private forest and brush-covered lands in cooperation with the State Forester, as well as work on lands within the Big Horn National Forest. The plan for treatment was developed by personnel of the Big Horn National Forest, and of the Wyoming State Forester's Office (under cooperative agreement with the U. S. Forest Service).

Total costs of treatment on non-federal forest and brush-covered lands will be $7,780. Of this, Public Law 566 will furnish $1,700 comprised of (1) $400 for fire control intensification ($200 technical assistance and $200 treatment) and (2) $1,300 technical assistance for improved forestry practices. Non-

P. L. 566 expenditures will be $6,080 comprised of (1) $3,980 for fire control intensification ($400 from State Division of Forestry funds and $3,580 from "going" forestry programs and other funds); and (2) $2,100 for improved forestry practices ($300 from State Division of Forestry watershed funds and $1,800 from "going" forestry programs and other funds).

Total costs of treatment on National Forest land will be $47,850. Of this, Public Law 566 will furnish $19,800 comprised of (1) $13,600 to obtain proper range use, (2) $3,400 for roadside erosion control and (3) $2,800 for fire control intensification. Non-P. L. 566 expenditures on National Forest land will be $28,050 comprised of (1) $5,100 to obtain proper range use, (2) $250 for roadside erosion control, (3) $15,700 for fire prevention and control, and (4) $800 for recreation management.

Structural Measures

The estimated contract cost, including a 10 per cent contingency, for the Dull Knife irrigation reservoir is $380,515. The unit values used for estimated contract costs are based on unit bid prices for similar work in a similar location. Allowances have been made for obtaining construction materials at known locations. Installation services are estimated to cost $77,720. Of this amount, $40,800 is for engineering services and $36,920 is for other costs associated with the installation of the reservoir. Engineering costs are for construction surveys, final design, preparation of detailed construction plans, and supervision of construction. Other installation service costs are administration and overhead costs.

Included are costs for cartographic, soils laboratory, technical assistance, and general administration. These installation service costs are based on costs for similar Public Law 566 projects. They are based on a detailed analysis of requirements for construction surveys, foundation investigations, the preparation of detailed construction plans, and supervision of construction.

Easement and rights-of-way costs of $15,900 include estimated costs for land acquisition, county road relocation, including a new county bridge and the construction of right-of-way fence. Land costs of $6,210 are based on recent land sales in the same general area and with similar characteristics. Costs for the road relocation and bridge construction, $5,460, are based on a consiruction estimate.

Water right costs of $200 are for amending the existing application of the North Fork Water Users Association and perfecting a permit to store.

An estimate of $5,000 has been made for contract administration costs. These costs include forming a legal entity, obtaining data to close a loan, and the administration of the construction contract.

In consideration of the size and cost of the Dull Knife Reservoir Dam, the Federal contribution to the installation cost is equivalent to the present worth of the interest foregone on an interest-free loan for the total amount of the installation cost during a 50-year amortization period. This amount is 48 per cent of installation costs. The installation costs are distributed as follows:

	P. L. 566	Other	Total
Construction Cost	$ 152,360	228,155	380,515
Installation Services	77,720	--	77,720
Land Easements and R/W	--	15,900	15,900
Water Rights	--	200	200
Administration of Contracts	--	5,000	5,000
Total Installation Costs	$230,080	$249,255	$479,335
Percentage of Total Costs	48%	52%	100%

Fiscal Year Obligations

The estimated Public Law 566 and other obligations for each year of the five-year installation period are as shown in the following table.

FISCAL YEAR OBLIGATIONS
(DOLLARS)

	STRUCTURAL PROGRAM		LAND TREATMENT							
			S. C. S.		F. S.				B. L. M.	
	P.L. 566	Other	P.L. 566	Other	Non-Fed. 566	Non-Fed. Other	Federal 566	Federal Other	P.L. 566	Other
1st Year	77,685	101,300	7,260	26,410	600	800	5,400	6,200	4,000	12,500
2nd Year	123,260	147,955	7,260	37,940	300	1,000	5,400	5,600	3,000	1,100
3rd Year	27,060		7,260	45,830	300	1,200	3,600	5,600	1,000	1,700
4th Year	2,075		7,260	53,955	300	1,500	2,800	5,600		500
5th Year			7,260	66,180	200	1,580	2,600	5,050		500
TOTALS	$230,080	$249,255	$36,300	230,315	1,700	$6,080	19,800	$28,050	$8,000	$16,300

EFFECTS OF WORKS OF IMPROVEMENT

Flood Prevention

Land treatment measures above the Dull Knife Dam will result in reduced erosion and sedimentation, improved vegetative cover, and a higher level of management. The development of management plans for state and privately-owned forest and brush-covered lands will result in increased income from these lands. Economic pressures to change land use on over-cut timber sites will be reduced, helping to maintain proper land use.

Treatment on Federal rangeland managed by the Bureau of Land Management will reduce damages to canals and irrigated cropland from upland runoff. The lower sediment delivery rates will result in lower operation and maintenance costs to canal systems.

Proper use on private, state, and federal range lands will result in improved vegetative conditions, and higher economic returns.

Agricultural Water Management

Thirteen ranches, with 2,807 irrigated acres, will benefit from the stabilized water supply provided by the Dull Knife irrigation reservoir.

A stabilized water supply will increase the project acreage of tame hay to 2,108 acres, the acreage of small grain to 910 acres, and irrigated pasture to 382 acres. The present acreage of native meadow (127 acres) will be shifted to crops with higher returns. Alfalfa yields are expected to increase from 1.80 tons per acre to 3.25 tons per acre. A full water supply will almost double the carrying capacity in animal unit months of irrigated pasture. The production of additional forage and feed, integrated with proper rangeland use, will alleviate the hazards of year-round grazing and eliminate improper seasonal use.

Natural stream flow and storage at the Dull Knife Irrigation Reservoir will provide a full season's water supply 80 per cent of the time. Adequacy of the proposed water supply is dependent upon obtaining field irrigation efficiencies of 59 per cent. Present field efficiencies are about 40 per cent. At the present time, ditch number seven (Cellars) is receiving a full supply. The remaining 2,807 acres receive a partial supply. With the project fully installed, a full supply will still be available for ditch number seven and an 80 per cent chance supply for the remaining 2,807 irrigated acres.

The Dull Knife Reservoir is the only feature of the project that will have a significant effect on fish and wildlife. It will affect the local fishing by creating an additional place to fish and by superimposing a different stream regime on the North Fork of Powder River below the dam site. The minimum flow of 2.5 c.f.s., to be maintained from September through March, will preserve the stream as a fishery.

Installation of the Dull Knife Dam and Reservoir will result in incidental recreational benefits. The Big Horn Mountains are among the most scenic in Wyoming; and the creation of a sizable body of water with good access will result in fishing, boating, camping, and picnicing activities. Free public fishing will be permitted in the reservoir waters and considerable use is expected. Public recreation is not a project purpose and any basic recreation facilities that will be developed will be by private enterprise.

Return flows, surface and subsurface will be used to augment the irrigation water supply. However, return flow from the lower ranches cannot be recovered and re-used within the North Fork Watershed. An estimated 800 acre feet of non-recoverable return flow and operational losses will occur during July and August. This water will be available to the Sussex area on the Middle Fork of Powder River. There are 4,962 acres irrigated from the Sahara Canal, whose diversion is downstream from the point where the North Fork enters the Middle Fork of Powder River. The Sussex area experiences a late season water shortage--return flows from the North Fork of Powder River Watershed will directly benefit irrigators under the Sahara Canal.

PROJECT BENEFITS

Agricultural Water Management

The purpose of this project is to furnish a supplemental irrigation water supply to 2,807 acres of irrigated land.

Net change of income is the basis for estimating net primary agricultural water management benefits. These benefits can be realized only in association with the installation of essential land treatment measures as summarized in Table 1. The annual net primary benefits resulting from supplemental water supply are estimated at $24,185 (Table 6).

Public Benefits

It is estimated that return flow and operational losses will result in 800 acre feet of water flowing out of the watershed in July and

August. This volume of water is the sum of return flow from about 233 acres served by the two lowest canals and the estimated project operational losses. The return flow is primarily surface runoff from irrigated fields. Operational losses or regulation wastes are derived from losses that occur in regulating stream flows. Because of the geographical location of these losses, they are not available to lands within the watershed. This water will be available to the Sussex area and other downstream users. Benefits will occur outside of the project area from the use of this water on land that is irrigated with natural stream flow in May and June, but which experiences a late season water shortage. The annual value of these benefits is estimated at $4,720.

Secondary Benefits

The project will not produce secondary benefits of National significance. However, it will increase agricultural production in the area, provide ranchers with a higher and more stable income, provide a market for additional equipment and supplies, and stimulate business in towns near the watershed. The secondary benefits stemming from, and induced by the project are estimated at $5,355 annually. The procedures outlined in Watershed Memorandum SCS-57 were used to evaluate secondary benefits.

Other Benefits

This project will improve the local economy by providing both an increased and a more stable income. Recreation is not a planned purpose of the project, but minor recreation benefits will accrue to the water supply reservoir.

COMPARISON OF BENEFITS AND COSTS

When the structural measures for agricultural water management are installed and operating at full effectiveness, the average annual primary benefits will amount to $24,185. The average annual cost of the structural measures totals $18,205, resulting in a ratio of primary benefits to costs of 1.3 to 1.0. Public benefits are estimated at $4,720 and secondary benefits are about $5,355 annually. Total project benefits are estimated at $34,260, resulting in a benefit cost ratio of 1.9 to 1 (Table 6).

All installation costs of the irrigation water supply reservoir are allocated to agricultural water management.

PROJECT INSTALLATION

The plan for the development of the North Fork of Powder River Watershed will be installed within a five-year period.

Accelerated land treatment needs will require the entire five-year period. Proper range use and proper irrigation water management are the primary needs on private and state lands. Both of these practices are dependent on other measures and most of the planned amounts will not be installed until the fourth and fifth year of the installation period. On National Forest lands and state-owned forest lands, erosion control and abatement of fire hazard will receive first priority. Other measures will be installed during the remainder of the project period. Measures on Bureau of Land Management lands will largely be installed by the third project year.

Two construction seasons will be needed to construct the Dull Knife Dam. Assuming that construction is started by June 1, the first year's work will consist of timber clearing, core trench excavation and backfill, spillway excavation, construction of the outlet conduit and relocation of the county road and bridge. The second construction season, stream closure, embankment, riprap, control gates, fencing, and vegetative seeding will be accomplished.

The Powder River and Lake De Smet Soil and Water Conservation Districts will be responsible for installing land treatment measures on private lands and on state non-forested lands. Measures will be installed by individual ranchers under cooperative agreement with the Powder River and Lake DeSmet Soil and Water Conservation Districts. Accelerated technical assistance for the installation of practices will also be furnished through the Soil and Water Conservation Districts.

The local ranchers are forming a non-profit stock company organized under the corporation laws of Wyoming. The stock company will become a co-sponsor of the project.

Under Wyoming Statutes, non-profit stock companies, organized for irrigation purposes, have the necessary legal authority, including the right of eminent domain, to carry-out the works of improvement. All of the powers provided by state law, including the right of eminent domain, will be used if necessary to achieve the objectives of the project. The same authority will be used to operate and maintain the works of improvement and to liquidate any indebtedness incurred in the installation of the structural measures.

All land rights will be acquired within the first year of the project installation period.

As a co-sponsor, it will be the responsibility of the non-profit irrigation company to install the project structural measures. Responsibilities will include advertising for bids, letting a construction contract, appointing a contracting officer, and accepting the completed works of improvement. As the local contracting organization, the irrigation company will obtain all land easements and rights-of-way,

as well as perfect their storage right. Relocation of the county road and bridge is an easement and right-of-way item.

Technicians of the Soil Conservation Service will assist the irrigation company in the planning, design, preparation of specifications, supervision of construction, contract estimates, final inspection, and other duties associated with the installation of structural measures.

The Forest Service, U. S. Department of Agriculture; and the Bureau of Land Management, U. S. Department of the Interior; administer Federal lands within the watershed. Land treatment measures on these lands will be installed by the agency responsible for, or administering the lands. The measures each agency will install and maintain are shown in Table 1. Technical assistance for land treatment measures on forest and brush-covered state, and private lands will be provided by the State Division of Forestry (Office of the Commissioner of Public Lands) under a cooperative agreement with the Forest Service, U. S. D. A. Each participating agency has developed the land treatment program for lands within its jurisdiction and has approved the measures and proposed rates of installation.

Easements and rights-of-way for the reservoir pool, dam site, spillway, and county road relocation will be obtained by the non-profit irrigation company. A water right application for the storage of 16,000 acre feet of supplemental irrigation water was filed with the State Engineer's Office in 1959 by the North Fork Water Users Association. The State Engineer's Office has assured the sponsors that this application will be approved for 4,230 acre feet of storage upon receipt of detailed plans. The date of priority will be that of the original application.

FINANCING PROJECT INSTALLATION

The total installation cost of the project is $825,880. Public Law 566 will provide $295,880. Local interests, and other Federal authorities will provide $530,000.

Farm owners and operators cooperating with the Powder River and Lake De Smet Soil and Water Conservation Districts will establish the land treatment measures on private land shown in Table 1. The estimated cost of installing these measures is $266,615. Private and other program funds will provide $223,255 to install these measures.

Technical assistance estimated at $36,300 will be provided from P. L. 566 funds to accelerate the application of land treatment measures. Other funds will provide $7,060 of technical assistance under going programs.

The Bureau of Land Management will use $8,000 of P. L. 566 funds and $16,300 of going program funds to establish the needed land treatment measures on Federal lands under their management.

The Forest Service will use $21,500 of P. L. 566 funds to establish land treatment measures on Federal, state, and privately-owned forested lands. The going program of the Forest Service will provide $34,130 to establish land treatment measures.

The estimated installation cost of structural measures is $479,335. The P. L. 566 share is $230,080. The amount to be provided by local interests is $249,255.

The North Fork of the Powder River water users have employed an attorney. Initial action is being taken to organize a non-profit stock company under the corporation laws of Wyoming. Under Wyoming statutes, this type of irrigation company has all of the powers and authority needed to construct, operate, and maintain the structural works of improvement. The irrigation company will acquire the necessary land, easements and rights-of-way for the works of improvement. All of the powers provided them by State laws, including the right of eminent domain, which such companies have under Wyoming statutes, will be used to achieve project objectives, if necessary.

The Powder River and Lake DeSmet Soil and Water Conservation Districts, as co-sponsors of the work plan will support the formation of the irrigation company and actively co-operate with the stock company during the installation of the project.

The local organization will obtain a loan from the Farmers Home Administration under the provisions of Section 8 of the Watershed Protection and Flood Prevention Act to meet its obligations. A letter of intent has been filed with the Farmers Home Administration. Federal assistance for carrying out the work plan will not be provided until the formation of a non-profit stock company has been completed under the corporation laws of Wyoming.

Amortization of the local share of the installation cost at the present long-term borrowing rate, over a 50-year repayment period would amount to about $9,570 annually. In addition, annual assessments of $2,520 will be made for operation, maintenance, and replacement. This amount will be collected annually until a revolving fund equal to about 5 per cent of the construction cost is established. This fund will be maintained at that level. Annual repayment costs and operation and maintenance costs are well within the repayment ability of local operators.

When all the legal requirements have been met, $295,880 of Public Law 566 funds will be made available for the installation of project measures. This includes $37,800 for accelerated technical assistance $230,080 for agricultural water management, and $28,000 for accel-

erating land treatment on Federal land. These funds will be made available through the Soil Conservation Service under the authority of the Watershed Protection and Flood Prevention Act (P.L. 566 - 83 Cong. 68 Stat. 666) as amended. The availability of these funds is contingent upon appropriations by Congress for this purpose.

PROVISIONS FOR OPERATION AND MAINTENANCE

Land treatment measures installed by cooperating ranchers on private lands will be operated and maintained by the individual land owners and operators. Maintenance of measures will be encouraged and specifications for maintenance stated in the ranch plans for conservation operations between individual ranchers and the Powder River and Lake De Smet Soil and Water Conservation Districts.

Land treatment measures installed on National forest lands or on National reserve lands will be maintained by the agency administering the land. Maintenance costs will be paid for from the regularly-appropriated funds of the agency concerned.

The irrigation company will operate and maintain the Dull Knife Reservoir. Reservoir operation will be minor. Stops will be placed in the slide gate to insure minimum releases for fish. The only other operation will consist of gate regulation to balance stream inflow and storage releases against irrigation demands. The State Engineer's Office grants authority to operate the facility by the execution of a "Certificate of Completion".

Maintenance of the structure should normally consist of the repair or replacement of the control gate, or gate seat, and the repair or strengthening of spillway riprap. However, unforeseen damages can occur and a revolving maintenance fund amounting to five per cent of the contract cost will be established. Annual payments of $2,520 will establish such a fund in about seven years.

The irrigation company will execute an operation and maintenance agreement with the Soil Conservation Service. The agreement will be for the structural works of improvement and be completed prior to a project agreement.

Inspection of the structural work of improvement will be made annually. An inspection committee made up of representatives of the sponsoring organizations and the Soil Conservation Service will make the inspection at the close of each irrigating season and prepare a joint report. The maintenance report will outline any work to be done and establish when the work is to be completed. The report and a record of actions taken will be kept on file by the organization charged with operation and maintenance.

TABLE I ESTIMATED PROJECT INSTALLATION COST

North Fork Powder River Watershed - Wyoming

Installation Cost Item	Unit	Number			Estimated Cost Dollars 1/						
					P. L. 566 Costs			Other			
		Fed. Land	Non-Fed Land	Total	Federal Land	Non-Fed Land	Total	Federal Land	Non-Fed. Land	Total	Total
Land Treatment											
Soil Conservation Service											
Cropland	Acres		3,300	3,300					100,045	100,045	100,045
Grassland	Acres		119,624	119,624					123,210	123,210	123,210
Technical Assistance						36,300	36,300		7,060	7,060	43,360
SCS Subtotal						36,300	36,300		230,315	230,315	266,615
Bureau of Land Management											
Grassland	Acres	27,047		27,047	8,000		8,000				8,000
Woodland	Acres	14,170		14,170				14,000		14,000	14,000
Technical Assistance								2,300		2,300	2,300
BLM Subtotal					8,000		8,000	16,300		16,300	24,300
Forest Service											
Woodland	Acres	6,308	5,738	12,046	6,200	200	6,400	22,950	4,195	27,145	33,545
Grassland	Acres	3,556		3,556	13,600		13,600	5,100		5,100	18,700
Technical Assistance						1,500	1,500		1,885	1,885	3,385
F. S. Subtotal					19,800	1,700	21,500	28,050	6,080	34,130	55,630
TOTAL LAND TREATMENT					27,800	38,000	65,800	44,350	236,395	280,745	346,545

TABLE I (Continued)

North Fork Powder River Watershed - Wyoming

Installation Cost Item	Unit	Number			Estimated Cost Dollars 1/						
					P. L. 566 Cost			Other			
		Fed. Land	Non-Fed. Land	Total	Federal Land	Non-Fed. Land	Total	Federal Land	Non-Fed. Land	Total	Total
Structural Measures											
Soil Conservation Service											
Irrigation Reservoir	No		1	1		152,360	152,360		228,155	228,155	380,515
Subtotal Construction			1	1		152,360	152,360		228,155	228,155	380,515
Installation Services											
Soil Conservation Service											
Engineering Services						40,800	40,800				40,800
Other						36,920	36,920				36,920
Subtotal Installation Services, SCS						77,720	77,720				77,720
Other Costs											
Land Easements and R/W									15,900	15,900	15,900
Administration of Contracts									5,000	5,000	5,000
Water Rights									200	200	200
Subtotal Other									21,100	21,100	21,100
TOTAL STRUCTURAL MEASURES						230,080	230,080		249,255	249,255	479,335
TOTAL PROJECT					27,800	268,080	295,880	44,350	485,650	530,000	825,880
Summary											
Subtotal SCS						266,380	266,380		479,570	479,570	745,950
Subtotal BLM					8,000		8,000	16,300		16,300	24,300
Subtotal FS					19,800	1,700	21,500	28,050	6,080	34,130	55,630
TOTAL PROJECT					27,800	268,080	295,880	44,350	485,650	530,000	825,880

1/ 1963 Price Base

Date: April, 1963

TABLE 2 - ESTIMATED STRUCTURAL COST DISTRIBUTION

North Fork Powder River Watershed, Wyoming

(Dollars) 1/

Structure	Installation Cost P. L. 566 Funds				Installation Cost - Other Funds					Total Install Cost
	Construction	Install Services		Total P.L. 566	Construction	Adm. of Contracts	Ease-ments & R/W	Water Rights	Total Other	
		Engin-eering	Other							
Dull Knife Reservoir Irrigation	152,360	40,800	36,920	230,080	228,155	5,000	15,900	200	249,255	479,335
Total	152,360	40,800	36,920	230,080	228,155	5,000	15,900	200	249,255	479,335

1/ Price base 1963

Date: April 1963

TABLE 2A - COST ALLOCATION AND COST-SHARING SUMMARY

North Fork Powder River Watershed, Wyoming

(Dollars) 1/

Item	Purpose	Total
	IRRIGATION	
	COST ALLOCATION	
Dull Knife Reservoir	479,335	479,335
Total	479,335	479,335
	COST-SHARING	
P. L. 566	230,080	230,080
Other	249,255	249,255
Total	479,335	479,335

1/ Price Base 1963 Date: April, 1963

TABLE 3 - STRUCTURE DATA

DULL KNIFE RESERVOIR

North Fork Powder River, Watershed, Wyoming

ITEM	UNIT	TOTAL
Drainage Area	sq. mi.	25.9
Storage Capacity		
Sediment	ac. ft.	135.
Irrigation Water Supply	ac. ft.	4,095.
Total	ac. ft.	4,230.
Surface Area		
Sediment Pool	ac.	19.5
Irrigation Water Supply Pool	ac.	129.4
Volume of Fill	cu. yds.	263,760.
Elevation Top of Dam	ft.	8,151.
Maximum Height of Dam	ft.	79.
Emergency Spillway		
Crest Elevation	ft.	8,145.
Bottom Width	ft.	40.
Type		Natural Rock
Percent Chance of Use		80.
Ave. Curve No. - Cond. 11		67.
Emergency Spillway Hydrograph		
Storm Rainfall (6-hr.)	in.	1.8
Storm Runoff	in.	0.13
Velocity of Flow (Vc) 1/	ft./sec.	4.3
Discharge Rate 1/	c.f.s.	100.
Max. w.s. elev. 1/	ft.	8,146.2
Freeboard Hydrograph 3/		
Storm Rainfall (6-hr.)	in.	3.0
Storm Runoff	in.	0.60
Velocity of Flow (Vc) 1/	ft./sec.	8.8
Discharge Rate 1/	c.f.s.	860.
Max. w.s. elev. 1/	ft.	8,149.1
Principal Spillway 2/		
Capacity Equivalents		
Sediment Volume	in.	0.10
Spillway Storage	in.	0.49
Class of Structure		B

1/ Maximum during passage of hydrograph.
2/ Combined with emergency spillway; maximum flow for 75 year frequency is 550 c.f.s.
3/ Maximum spillway capacity, 1,600 c.f.s.

Date: April, 1963

TABLE 4 - ANNUAL COST

North Fork Powder River Watershed, Wyoming (Dollars) 1/

Evaluation Unit	Amortization of Installation Cost 3/	Operation, Maintenance and Replacement Cost 2/	Other Economic Costs	Total
Irrigation	15,650	2,520	35	$ 18,205
TOTAL	15,650	2,520	35	$18,205

1/ Price base 1963

2/ Based on long term projected prices

3/ Amortized at 2 7/8 percent interest over 75-year period

Date: April 1963

TABLE 5 - ESTIMATED AVERAGE ANNUAL FLOOD DAMAGE

REDUCTION BENEFITS

North Fork of Powder River Watershed, Wyoming

(N O T A P P L I C A B L E)

TABLE 6 - COMPARISON OF BENEFITS AND COSTS FOR STRUCTURAL MEASURES

North Fork Powder River Watershed, Wyoming

(Dollars) 1/

Evaluation Unit	AVERAGE ANNUAL BENEFITS				Average Annual Cost	Benefit Cost Ratio
	Irrigation	Public	Secondary	Total		
	(Dollars)	(Dollars)	(Dollars)	(Dollars)	(Dollars)	(Dollars)
Bull Knife Reservoir						
Total Benefits	24,185	4,720	5,355	34,260	18,205	1.9:1
TOTAL	24,185	4,720	5,355	34,260	18,205	1.9:1

1/ Long term prices were used for benefits and O and M and 1963 prices for annual installation costs.

Date: April, 1963

INVESTIGATIONS AND ANALYSES

ECONOMIC INVESTIGATIONS

Economic investigations and the analysis of benefits followed the procedures outlined in Chapter 8 of the Economic Guide.

Long term prices, as projected by the Agricultural Research Service, September, 1957, were used to determine benefits and operation and maintenance costs. Current prices (1963) were used for installation costs. Federal and non-federal costs were amortized at 2-7/8 per cent interest over a 75-year evaluation period.

Contingencies were computed at 10 per cent of the engineering estimate. Installation service costs are based on estimates of engineering services and other costs necessary to install the project.

Costs of land easements and rights-of-way are based on estimates of local people and recent land sales. These costs are slightly less than the capitalized value of the net return to lands being acquired for easements and rights-of-way. The difference between the amortized value of the estimated cost and the value of the net return is shown as an annual cost under other economic costs, (Table 4).

Average annual operation and maintenance costs were computed at 0.75 per cent of the construction cost converted to long-term projected prices.

Analysis of Agricultural Water Management Benefits

Agricultural water management benefits were computed by land use capability classes. Detailed soil surveys were available on 40 per cent of the irrigated lands needing a supplemental water supply. The local soils technician estimated land use capability classes on the remainder of the irrigated lands by field reconnaissance and inspection.

The following is a summary of land use capability classes on irrigated lands:

Land Use Capability	Acres	Per Cent
I	15	.5
IIw and IIwl	11	.3
IIs5	116	3.5
IIe2	565	17.1
IIsl	129	3.9
IIs16	63	1.9
IIIw10, IIIwl, and IIIw2	66	2.0
IIIel	341	10.3
IIIe2	781	23.7
IIIe3	75	2.3
IIIe5	158	4,8
IIIsl	19	.6
IIIs4	16	.5
IIIs7	132	4.0
IVel	150 +	4.6
IVe2	111	3.4
IVs9	21	.6
IVs10	271	8.2
IVs12	249	7.5
VIs9	11	.3
TOTALS	3,300	100.0

Land use and crop distribution were mapped in place on all irrigated lands. Present and future yields, production costs and the estimated cropping program on irrigated lands with the project installed was determined by schedules and interviews with land owners and local technicians.

Single enterprise crop income and cost data was developed for land use capability classes to obtain net farm income for the different crops and yields. The following table is a summary of crop distribution yields and net income for present conditions on lands having a short water supply.

Present Farm Conditions Without Project, Short Water Supply

Crop	Long-Term Prices Acres	Yield	Net Income 1/ Per Acre (Dollars)	Total (Dollars)
Tame Hay	1,996	1.8 ton	11.94	23,830
Native Meadow	127	0.8 ton	5.94	755
Oats	202	40 bu.	5.79	1,170
Irrigated Pasture	202	2.8 A.U.M.	12.91	2,605
Meadow Aftermath		0.9 A.U.M.		6,070
Total	2,527			34,430

Average net return per acre -- $13.63.

1/ Gross value of production less growing, storing, marketing, and all other production costs except land.

A similar analysis was made for 773 acres--the acreage that receives a full water supply under present conditions; for 813 acres--the acreage that could receive a full water supply without storage; but with an installed land treatment program; and for 3,300 acres--the acreage that would receive an adequate supply 80 per cent of the time with the complete project installed. A summary of the analysis of primary benefits is shown in the following table:

NORTH FORK POWDER RIVER WATERSHED
ANALYSIS OF INCREASED PRODUCTION BENEFITS

	Acres	Weighted Net Income Per Acre	Net Income Before Cost of Land Treatment Measures Are Subtracted	Average Annual Cost of Pre-Project Land Treatment	Average Annual Cost of Accelerated Land Treatment	Total Average Annual Cost of Land Treatment 2/	Total Net Income
Present Non-Project Conditions							
Full Irrigation	773	$18.18	$14,055				
Partial Irrigation	2,527	$13.63	$34,430				
Total			$48,485				$48,485
With Land Treatment No Project							
Full Irrigation	813	$19.29	$15,685 1/				
Partial Irrigation	2,487	$13.63	$33,900				
Total			$49,585 1/	$925		$925	$48,660
With Accelerated Project L.T.							
Full Irrigation	863	$23.97	$20,685				
Partial Irrigation	2,437	$13.68	$33,215				
Total			$53,900	$925	$310	$1,235	$52,665
With Accelerated Project L.T. and Water Storage							
Full Irrigation	3,300	$23.97	$79,090	$925	$5,320	$6,245	$72,845
Total Net Primary Benefits							$24,185

1/ Net income and land treatment costs discounted 5 years @ 5%, 75-year period.
2/ Associated on farm capital cost of land treatment, replacement, and O. and M.

Incidental Water Conservation Benefits

The annual return flows and operational losses are estimated at 800 acre feet. This water will be available to the Sussex area or other downstream areas during July and August. It was estimated that the value per acre foot would be equal to the net values per acre foot of supplemental water provided for the North Fork of Powder River Project. These average annual benefits which accrue outside the project area are estimated at $4,720.

Secondary Benefits

Secondary benefits were evaluated by the procedures outlined in Watersheds Memorandum SCS-57. These benefits, stemming from and induced by the project accrue in the form of increased income to processors of agricultural products, to business establishments in the local trade area, and to individuals other than the direct primary beneficiaries. The annual value of secondary benefits is estimated at $5,355.

SEDIMENTATION INVESTIGATIONS

No sediment data are available in or near the watershed. In order to establish sediment storage needs at the proposed structure, it was necessary to evaluate physical conditions within the watershed. Field reconnaissance, use of aerial photographs, and Forest Service base maps were used to determine sedimentation and erosion rates.

Measurement of sheet erosion was computed by use of a modified Musgrave formula which employs factors of slope, land use, soil erodibility, and maximum thirty-minute, two-year frequency precipitation. Evaluation factors were compiled from aerial photographs and basic data developed by the U. S. Forest Service in their hydrologic evaluations.

Gully and streambank erosion is small. Swale areas and upland channels are well grassed and only a few minor isolated headcuts are present. Sediment yield from this source is minor.

Sediment storage in the reservoir site for a 75-year accumulation was computed on the basis of present land use and future land use with needed land treatment measures installed. The estimated future rate was based on the premise that the needed land treatment measures would be installed 10 years after project installation. It is estimated that the installation of needed land treatment measures will reduce the present rate of sedimentation above the reservoir site approximately 7 per cent.

Random measurements were made along the floodplain of the North Fork to determine the extent and quality of sediment deposition on irrigated meadows. Since damage was minor, no detailed valley cross-sections were made. Irrigation distribution systems were visually examined to determine sediment damage and potential seepage losses.

Gullied areas below the planned structure were observed and evaluated by field inspection and the use of aerial photographs. Where land stabilization measures appeared to be economically justified, they were included in the land treatment program.

SOIL SURVEYS:

Existing soil surveys on irrigated lands were revised, and where standard soil surveys were not available, an abbreviated reconnaissance-type survey was made. The purpose of the survey was to determine irrigation site indexes, the characteristics and capabilities of the irrigated soils. The results of the survey are as follows:

Capability Units 1, IIe2, IIIe2, IVe2, IIs16, Approximately 1,473 Acres

Deep, moderately dark colored, medium to moderately-fine textured, moderately permeable soils, occurring on slopes of 1 to 9 per cent. Water erosion is the primary hazard of the soils in this group. This hazard increases with slope as reflected in the capability class.

Capability Units IIs1, IIIe1, IVe1, IIIe3, Approximately 715 Acres

Deep, fine textured, moderately permeable soils, occupying nearly level river bottoms and sloping fans with slopes ranging from 1 to 9 per cent. Soils in the IIIe3 Unit are highly calcareous. Erosion is the primary hazard of these soils, increasing with slope. Workability of this group is affected by the fine texture, requiring timeliness of tillage operations.

Capability Units IIs5, IIIe5, IIIs4, Approximately 323 Acres

Deep, moderately coarse, and coarse textured, moderately to rapidly permeable soils occupying nearly level bottoms and gently sloping river terraces of 2 to 5 per cent slope. These soils are highly susceptible to wind and water erosion. Water erosion hazard increases with slope.

Capability Units IVs10, IVs12, Approximately 545 Acres

Deep, medium to fine textured soils that are moderately saline and/or sodic. Many soils of this group also have poor subdrainage

features and are affected by a water table. Soils of this group occur on slopes of 1 to 5 per cent and are situated on stream bottoms and fan terraces. Erosion is a hazard as protective cover is often difficult to establish. These soils have major limitations in salinity, sodic, and wet conditions. Water management and salt tolerant crops are important in the management of these soils.

Capability Unit IIIs7, Approximately 141 Acres

Deep, fine textured, slowly permeable soils occupying level to nearly level bottoms and low terraces of 1 to 2 per cent slope gradient. These soils are susceptible to wind erosion and slight water erosion due to granulation of the plow layer. The principal limitations are poor workability and slow permeability.

Capability Units IIw1, IIIw1, IIIw2, IIIw10, Approximately 94 Acres

This group consists of deep, moderately coarse to fine textured soils. Wetness varies from a beneficial water table to an adverse water table. Some soils of this group are slightly to moderately saline in addition to being wet. Subsurface features vary from gravelly to non-gravelly. These soils occur on nearly level to moderate slopes, of 1 to 5 per cent gradient. The primary hazards are increased wetness and salinity. Management of irrigation water is important, and drainage is desirable when substrata conditions are suitable.

Capability Unit VIs10, Approximately 9 Acres

Deep, medium to fine textured, strongly saline and sodic soils occupying nearly level to moderately sloping areas of 1 to 5 per cent slope gradient. Some of these soils are affected by slight to moderate wetness. Soils of this group are adversely affected by salinity and alkalinity and will support only the most salt tolerant forage crops. Water management is extremely important.

ENGINEERING INVESTIGATIONS

I. Irrigation - General The following data was obtained for estimating irrigation water requirements:

   1. A survey of irrigated land delineating areas by land capability class, intake family, and water-holding capacity.
   2. Relative seepage rates of canal reaches based on soil texture.
   3. Measured flow losses in representative reaches of canals. Acres irrigated were selected on the basis of land capability class, location below existing distribution canals, and indication of water application in past years.

II. Water Requirement The following procedure was used to estimate irrigation water requirement.

   1. Area Irrigated. Participating acres are all irrigated acres exclusive of those for which water is provided under

the adjudicated water right of first priority. The full water right of first priority is considered as non-participating because natural stream flows will supply the amount of the water right and the equivalent acres may not participate in the use of stored water.

2. Consumptive Use - Net Irrigation Requirement. Consumptive use was computed by the Blaney-Criddle method using variable consumptive use coefficients to determine monthly requirements. Average monthly precipitation was deducted from consumptive use to determine net irrigation requirement. Net irrigation requirement was weighted for a composite acre of anticipated crops.

   Net irrigation requirement used was 1.125 feet annually.

3. Recommended Net Application. Seasonal distribution of the net irrigation requirement was determined by adding two inches to the demand at the beginning of the irrigation season and deducting that amount from the demand at the end of the grazing season. Thus the fields will go into the winter with adequate soil reservoir capacity to store the natural moisture of winter and early spring. Most of the irrigated soil has good water-holding capacity, and the two inches of moisture can be stored in advance of crop needs.

4. Field Requirement. Field efficiencies were estimated for individual fields based on method of irrigation, amount of leveling expected, and field size and shape.

   Principal methods of water application will be border dike and contour ditch. Per cent efficiency, based on intake family and slope for border dike and on intake family and net application for contour ditch, was taken from the revised Irrigation Guides for Eastern Wyoming of the Soil Conservation Service. Weighted average field efficiencies weighted by acre were determined for each ditch.

   Estimated field efficiencies average 59 per cent.

5. Farm Requirement. Field ditch losses were estimated at 10 per cent per mile based on observed losses in canals. Field ditch lengths were estimated to average one mile.

   Estimated farm efficiencies average 53 per cent.

6. Gross Diversion Requirement. Gross diversion for the non-participating area is the 12.21 cubic feet per second water right of first priority.

   Canal losses were measured on representative reaches of canals rated as low loss and medium loss. No high loss ratings are included in canals serving participating acres. Ru values (in cubic feet of loss per square foot of wetted area per day per unit head) were computed from loss measurements as 1.0 for "low" loss reaches and 1.8 for "medium" loss reaches.

   Canal seepage and evaporation losses for an assumed canal cross-section and assumed average flow of 4 cubic feet per second and based on the above Ru values are 6 per cent and 10 per cent per mile for "low" and "medium" loss reaches respectively. Percentage losses were applied to the weighted (by acre) average length of each canal and an additional loss of 4 per cent was added to each ditch for individual operating losses, canal breaks, etc.

   Estimated canal efficiencies average 83 per cent. Estimated project efficiencies below diversions for participating acres average 44 per cent.

   Estimated seasonal gross diversion requirement is 2.53 feet for participating acres and 10,088 acre feet for total project.

7. Project Requirement at Diversion. Return flow to the North Fork of Powder River was estimated at 75 per cent of the loss below diversions.

   Return flow from all of the irrigated area with the exception of about 233 acres served by the lowest two canals is available to the irrigated lands within the project.

   Computed losses include the estimated losses from the non-participating area based on the adjudicated diversion volume for the four irrigating months and the recommended net application for 855 acres, the area included in the water right of first priority. Seasonal distribution of return flow was estimated as 8 per cent for May, 14 per cent for June, 16 per cent for July, and 15 per cent for August. The 50 per cent of return flow which is available to the watershed through the four irrigating months is about 38 per cent of the seasonal loss below diversions.

Estimated seasonal net diversion requirement is 7,846 acre feet.

8. Project Requirement Near Mayoworth. Near Mayoworth is the location of the first diversion from North Fork of Powder River. To project net diversion requirements to a project requirement near Mayoworth natural channel losses were considered to be 3/4 of 1 per cent per mile of valley length applied to inflow of each mile.

   More than 60 per cent of the water requirement will be supplied by natural stream flow. About 40 per cent of the watershed yield during the irrigating period will be uncontrolled, originating in the area between the proposed storage site and the irrigated area. These stream yields include wide variations in flow due to changes in snowmelt rate and to runoff from summer storms of short duration.

   The variations in rate of flow, unpredictable rate of flow from uncontrolled areas, the need for alternate storing and releasing from the reservoir in early summer, and the distance of the storage site from the irrigated area create operational problems in maintaining the stream flow at the rate required for irrigation while still retaining in storage the flows available to store. It is estimated that operational losses resulting from making water deliveries under the above conditions will be 15 per cent of the irrigation requirement near Mayoworth.

   Estimated natural channel losses below Mayoworth are approximately 7 per cent.

   Estimated annual irrigation requirement near Mayoworth is 8,424 acre feet. Including operational and conveyance losses, the annual requirement near Mayoworth is 9,688 acre feet.

9. Peak Requirement. Estimated peak net requirement of 0.27 inches per day was taken from Soil Conservation Service Irrigation Guide for Eastern Wyoming. The same efficiencies were used in estimating peak gross diversion requirements as in estimating monthly and seasonal gross diversion volumes. The peak net diversion requirement was estimated as the peak gross diversion requirement for participating acres plus 12.21 cubic feet per second for the non-participating area less the average July rate of return flow. Peak requirements at diversion were projected

to a peak release rate at the storage site using the same percentages of loss as were used in estimating monthly and annual volume requirements.

Estimated peak gross diversion is 73 cubic feet per second for participating acres and 85 cubic feet per second for project. Estimated peak requirement near Mayoworth is 80 cubic feet per second. Estimated peak release required at storage site is 90 cubic feet per second.

III. Supply and Storage Requirement

1. Yield. Water yields used in determining storage requirements are the monthly volumes of U.S.G.S. recorded flow and U.S.B.R. correlated flows for stations near Mayoworth and near Hazelton, the proposed reservoir site, for a period of 30 years, 1932 through 1961. Flows near Mayoworth are recorded for 21 years, 1941 through 1961, and correlated with Clear Creek near Buffalo for 9 years. Flows near Hazelton are recorded for 15 years, 1947 through 1961, and correlated with Clear Creek near Buffalo for 15 years.

   No reduction was made in recorded or correlated yields near Mayoworth for the loss of storm runoff of short duration. Such losses were included in the 15 per cent operational loss.

2. Demand. Irrigation demand used in determining storage requirement is the estimated average by monthly volumes. The diversion requirement of the non-participating area was supplied only when available from natural stream flows near Mayoworth.

   A continuous flow in the natural stream below the storage site is to be maintained for livestock use and for fish and wildlife. Operational studies indicated that without storing flows of the non-irrigation season, carry-over storage will be required. To make carry-over possible, winter outflow from storage must be limited. A flow of two and one-half cubic feet per second, the approximate maximum flow that will not reduce winter storage those years that carry-over storage is needed to supply the requirement of 80 per cent of the years,was used as a continuous winter release rate when available.

3. Storage Requirement. The storage required is based on an operational study for a period of 30 years, using the monthly volume of flow as recorded and correlated at the stations near Mayoworth and near Hazelton and the estimated average monthly demands for irrigation with provision for

a continuous flow of two and one-half cubic feet per second from the reservoir, when available, and with losses of stored water.

Natural channel loss of stored water was estimated as 3/4 of 1 per cent per mile for the valley length of 14 miles between storage site and the first diversion. Net reservoir evaporation was estimated from Soil Conservation Service monthly evaporation maps, Figure 9-1 of the National Engineering Handbook, Section 4, Chapter 9, and from precipitation records at Buffalo, Wyoming.

Estimated net evaporation losses are 80 acre feet for the period of September through April and 120 acre feet for July and August.

No estimate is made of evaporation loss in May and June as spill from the reservoir occurs in this period each year for which a full supply is provided for irrigation.

A storage volume of 4,095 acre feet was selected for operational studies. The storage to be provided is that storage which will supply the full irrigation demand 80 per cent of the years of operation and leave water shortages 20 per cent of the years. The minimum storage capacity required to provide the above conditions was computed at 3,780 acre feet, or 300 acre feet less than the estimated requirement of 4,095 acre feet. Required storage was increased 300 acre feet because of estimated reservoir losses due to seepage.

IV. Structural Measures

1. Surveys. The following data was obtained for planning the storage structure.

   (1) Centerline profile and topography of dam site.
   (2) Topography of spillway, borrow area, and reservoir area.
   (3) Profile of proposed road relocation.
   (4) Outline of reservoir clearing area.

V. Dam Site

A storage site is available near Hazelton, about 14 miles upstream from the first diversion.

The reservoir is suitable for storage of volumes of 3,000 acre feet to 20,000 acre feet with different embankment locations for the same reservoir pool area. Non-erosive rock spillways are available at each of the embankment sites. The site selected for embankment is the most economical for the storage of the required 135 acre feet of sediment capacity and the required 4,095 acre feet of irrigation water capacity. The embankment site is limited to storage of 4,300 to 4,500 acre feet. One spillway will be provided by excavating a non-erosive rock abutment. The height of embankment above the spillway crest will be six feet. The remote location of the dam makes a spillway depth of six feet desirable as an additional safety factor. A spillway width of 40 feet was selected to provide for a discharge of 1600 c.f.s. The spillway will discharge a peak flow equivalent to a 62 cubic feet per second from each square mile of drainage area and is based on a study of flow records at the sam site.

Release of water will be through a reinforced concrete conduit and controlled by a manually operated gate with inlet near the bottom of the reservoir and within the sediment pool. The conduit will have a capacity to release the peak requirement of 90 cubic feet per second with an irrigation storage of about 100 acre feet.

Passage of continuous flow for livestock and fish will be accomplished through an orifice into the irrigation water release tube. The orifice will have a capacity to release the desired two and one-half cubic feet per second with a reservoir storage equal to the sediment pool capacity.

VI. Alternate Structural Measures Considered

Lining canals or combining canals was considered to reduce storage requirement. Lining or reorganization is not justified to reduce the estimated 300 acre foot annual canal loss which is provided from storage.

GEOLOGIC INVESTIGATIONS

A geologic investigation was made of the Dull Knife Dam site in June, 1962. The investigation was made by using recognized geologic procedures, hand tools, other instruments and large exploratory drilling and access equipment. A centerline profile showing geologic conditions, a topographic map showing borrow areas, and a summary sheet (Form SCS-375) were prepared.

Prior to the field work, the Bureau of Reclamation geologic report of their Dull Knife Site was reviewed. This site is located about 1/4 mile downstream and has since been abandoned by the Bureau.

The foundation and emergency spillway investigation was carried out with the use of a rented bulldozer and Mayhew 1000 rotary drill rig which was equipped for both air and water drilling. The rig was also equipped with the specialized bits and tools required for this type of work.

The Soil Conservation Service power auger was used to test drill the borrow areas. Hand tools and survey instruments were also used along with Atterberg tests for borrow classification and volumes. Access roads were constructed to the test hole sites in the foundation and emergency spillway. The rotary rig was then tooled for the individual test hole conditions and the holes drilled and logged. The Unified Soil Classification System was used for the unconsolidated materials and geologic classifications for the bedrock material. Other features of the test drilling were noted such as the drawdown load applied to the bit. This was related to drilling speed to determine the depth of bedrock weathering. Also, water loss was estimated to determine permeability.

A grid system with a 100' interval was established on the borrow area and the grid stations test drilled. The holes were logged and the materials classified to the workable depth delineated by bedrock or a permanent water table. Large disturbed samples of the different types of fill material were collected for laboratory analysis to establish design criteria. The borrow area locations are shown on the topographic map. The volume of the different types of fill material available was computed.

The emergency spillway is located in hard and durable Pre-Cambrian crystalline rock and was drilled with air. The depth of bedrock weathering and volume of bedrock excavation was observed and may be computed when the design width and depth becomes known.

The center line of this structure requires a main dam with a lower level dike across the saddle which occurs in the right abutment area. The foundation of the main dam contains a water table which required drilling with water and mud. The foundation consists of a surface mantel of platy, angular boulders underlain by a silty sand gravel mixture which, in turn, is underlain by boulders lying directly upon the Pre-Cambrian crystalline bedrock. The boulders are composed of the crystalline bedrock material; therefore, it was necessary to drill a few feet into the bedrock to assure that bedrock was being encountered. This was very slow drilling because of the hard, durable granite-type of bedrock.

Storage Reservoir Site

The detailed subsurface exploration of the structure foundation and borrow areas was based on a structure with an anticipated height of about 90 feet containing about 240,000 cubic yards of earth fill material.

The center line of this structure requires a main dam with a lower level dike 25 feet high in the saddle which occurs in the right abutment area.

Pre-Cambrian igneous rocks consisting primarily of granites with associated schists and gneiss with basalt and quartz intrusives outcrops in the abutments and along the margin of the basin and were encountered in the foundation.

Foundation Conditions

The abutments and foundation of the main dam consist of the Pre-Cambrian crystalline rock. The foundation of the dike consists of the crystalline rock in the left abutment with the remainder of the foundation and right abutment composed of compacted dark Tertiary silts and clays.

The alluvium in the valley floor consists of well-graded, unconsolidated materials ranging in size from silt to boulders. It is rapidly permeable with the water table at creek level. This material sloughed readily during the test drilling.

The three test holes along the center line in the foundation of the main dam encountered granite at a depth of from 13 to 16 feet. The test hole in the upstream section hit the granite at a depth of 19 feet. The test hole in the downstream area was carried to a depth of 15 feet, where the driller indicated that he had encountered bedrock. This hole sloughed so badly that the drill rig was endangered, and it was not possible to continue drilling to ascertain the driller's statement; however, it is felt to be reliable for design purposes.

The upper 1 to 2 feet of the bedrock in the foundation is fractured; below that depth, it is solid and relatively unweathered.

It was not possible to test drill the steep abutments where the crystalline rock outcrops at the surface. These outcrops are severely fractured at the surface; however, based on the test hole on top of the left abutment and those in the emergency spillway, the degree of fracturing rapidly diminishes with depth. At a depth of between 5 and 7 feet the rock becomes hard and solid and relatively unweathered and unfractured.

The foundation and right abutment of the dike consists of a dark compacted Tertiary silt to a depth exceeding 105 feet in test hole #1 near the center of the saddle. The Tertiary silt extends up the left abutment to within a very few feet of the emergency spillway elevation. A granitic outcrop containing a near vertical intrusive quartz dike occupies the remaining higher portion of this abutment. This resistant dike extends roughly perpendicular to the center line.

Emergency Spillway

The emergency spillway is located in the right abutment area between the dam and the dike. The spillway will be cut through the granitic and quartz dam dike outcrop. Six test holes were drilled in the emergency spillway, four on center line and two offsets. Test Holes Nos. 201, 202 and 203 were drilled in the control section. The drilling indicates that the granitic bedrock is moderately weathered to a depth of 5 feet, slightly weathered between 5 and 7 feet, and relatively unweathered below that depth. The degree of weathering is relative in relation to erodibility in that even the moderately-weathered rock is of very low erodibility.

Test Holes No. 204 and 205 were drilled on center line in the forebay area. Test Hole 204 encountered 11 feet of an unconsolidated gravel, sand, silt, and clay mixture underlain by the compacted silt. Test Hole No. 205 encountered 9 feet of the unconsolidated material underlain by granite.

Test Hole No. 206 was drilled in the exit section and encountered unconsolidated gravelly sands to a depth exceeding 15 feet.

Borrow Material

Adequate borrow material is available at the site in two main borrow areas located on each side of the reservoir basin upstream from the center line. The borrow consists of unconsolidated alluvium composed of silts, sands, and clays (SM, SO, ML, & CL) with occasional fine angular gravel. No oversize was encountered above the water table. The water table gradient is quite steep away from the creek and is migratory varying directly with volume of runoff.

Seven large disturbed samples were collected from the borrow area.

The average haul will be about 1,500 feet with an estimated shrinkage of about 25 per cent.

Principal Spillway

The principal spillway may be located either in the left abutment or in the valley bottom. If located in the abutment, the hard crystalline rock that outcrops at the surface will have to be excavated by drilling and blasting. If located in the bottom, the alluvium may be classed as common excavation to the top of the bedrock, although an occasional-large boulder may be encountered. The foundation test holes indicate the unconsolidated valley alluvium to be 15 to 19 feet thick.

Riprap

Granitic outcrops near the dam will supply adequate riprap although blasting will be required to obtain the desired volume. Cobbles and boulders in the alluvium upstream from the dam may also be used for riprap.

Concrete Aggregate

Concrete may be hauled from Buffalo over good roads and as a dry mix. There are other possible sources from the valley alluvium near the site or the bench alluvium located about 2 to 3 miles northeast of the site. Either of these areas will require screening and washing which, in the case of the bench, will require a pipeline.

Summary and Conclusions

1. The foundation and abutments of the dam and dike are suitable for the proposed structure.
2. Adequate and suitable fill material is available at the site.
3. The floodplain portion of the core trench will require common excavation for the most part to a depth of about 15 feet. This portion will require dewatering during construction.
4. The abutments will require coring to a depth of about 7 feet with the first 5 feet being weathered rock excavation with heavy ripping equipment. The remaining 2 feet will be hard rock excavation.
5. The control section of the emergency spillway consists of hard and durable rock.
6. Riprap and aggregate are available although certain preparation such as blasting and washing may be required to obtain the necessary volume.
7. The compacted silts in the foundation and abutments of the dikes are suitable and sound. A core trench of about 10 feet in depth will be required here.

HYDROLOGIC INVESTIGATIONS

1. Yield

A. Source of Yield Data

Records of the stream gaging stations, North Fork Powder River near Mayoworth and North Fork Powder River near Hazelton provide yield data for the project at the point of the first diversion for irrigation and at the storage site respectively. Runoff records for the station near Mayoworth are available for a period of 21 years, from November 1940 to September 1961. Runoff records for the station near Hazelton are available for a period of 15 years, from September 1946 through September 1961.

Estimates to reconstruct stream flow at the station near Mayoworth for the period 1929 through 1941 were made by the U. S. Bureau of Reclamation by monthly correlation with recorded and estimated flows at the station Clear Creek near Buffalo, using concurrent records of April, 1941, through September, 1952. The correlated monthly yields for the period of September, 1931, through October, 1940, were used with available recorded yields to provide a thirty-year recorded and estimated yield near Mayoworth that includes the drought period of the 1930's.

Estimates to reconstruct stream flow at the station near Hazelton for the period 1929 to 1946 were made by the U. S. Bureau of Reclamation by monthly correlation with recorded and estimated flows at the station Clear Creek near Buffalo, using the concurrent records of 1947 to 1952. The correlated monthly yields for the period of September, 1931, through August, 1946, were used along with available recorded yields to provide a thirty-year recorded and estimated yield near Hazelton that also included the drought period of the 1930's.

B. Annual Yield and Seasonal Distribution

One half of the annual yield near Mayoworth occurs during the snowmelt period of late April to late June. Average annual yields near Mayoworth are 23,000 acre feet with forty percent occurring in May and June and 12 percent occurring in July and August. Eighty percent chance yields near Mayoworth for the irrigating months are 3,500 acre feet in May, 2,200 acre feet in June, 1,350 acre feet in July and 750 acre feet in August.

Three-fourths of the annual yield near Hazelton is snow melt which occurs about May 1 to June 30. Average annual yield near Hazelton is 9,800 acre feet with 70 per cent occurring in May and June. Eighty per cent chance annual yield near Hazelton is 7,000 acre feet.

2. Reservoir Operation

Reservoir operation studies indicate that with the proposed reservoir capacity of 4,230 acre feet:

A. The reservoir will fill, and spill will occur 24 out of 30 years if use is limited to estimated demand.
B. The volume of water available to store in May and June is greater than reservoir capacity 20 of 30 years.

C. Carryover storage is required to fill the reservoir four of the 24 years that spill occurs.

D. The estimated average irrigation water demand can be supplied 24 of 30 years.

E. The volume of water available to store in May and June exceeds the estimated demands from storage 21 out of 30 years.

Operational studies show that without carry-over storage of 1,000 acre feet shortages would occur fifteen years out of thirty. With carry-over storage, shortages are reduced to six years. Four of the years the shortage was from 18 per cent to 22 per cent. The other two years (1960-1961) were 33 per cent and 51 per cent. These were the only two years in which shortages were consecutive.

The shortage for one year is permitted to remain in the plans because to increase appreciably the supply would require a reservoir of large capacity and a storage structure of excessive cost. An increased storage capacity does not result in a corresponding increase in irrigation water supply. To provide a full season supply for the year of shortest supply would require carryover for six years and a reservoir capacity of 11,000 acre feet.

A season of extreme shortage can be expected to occur during the life of the project.

3. Spillway Design

The hydrologic condition of the watershed above the storage site was investigatdd by the U. S. Forest Service. The drainage area of 25.9 square miles, a runoff curve number of 67 and a time of concentration of 2.5 hours were assigned to the drainage area above the site.

The runoff curve number was determined by dividing the drainage area into four hydrologic types by land use or cover: (1) Forest, (2) Range, (3) meadow, and (4) rock.

Forest, 57 per cent of the area, was placed in hydrologic soil group C and a hydrologic condition class of near IV (good). The resulting runoff curve number is 64.

Range, including all grass, forb, and sagebrush covered lands except wet meadows, and comprising 32 per cent of the area was placed in hydrologic soil group C and a fair range hydrologic condition. The assigned runoff curve number is 70.

Wet meadow, adjacent to streams and in low pockets, is four per cent of the area. The runoff curve number of 46 is based on a ground cover density of 83 and hydrologic soil group C.

The rock type along the high slopes of the drainage and in occasional rock outcrops makes up 7 percent of the drainage area. Based on an 0 to 20 per cent vegetative cover and a D soil group, the runoff curve number of the rock type is estimated to be 90.

An estimated maximum possible improvement potential for the drainage area for a one hundred-year period reduces the runoff curve number from 67 to 63.

Emergency spillway hydrographs and freeboard hydrographs were computed by the procedure contained in Part 3.21 of the Soil Conservation Service National Engineering Handbook, Section 4, Supplement A. The three-inch precipitation in figure 3.21-2 was used as point rainfall. The contributing area is above 8,000 feet m.s.l. and the three inch was judged more appropriate for the hydrographs than the five-inch precipitation shown in figure 3.21-1. The freeboard hydrograph computed by the above procedure has a peak inflow rate of 2,600 c.f.s. and a total volume of 830 acre feet.

A study of past stream gage records indicates that the peak discharge at the dam site for a flood event having a recurrence interval of 50 years equals 520 c.f.s. Because the emergency spillway is constructed in non-erosive rock, this spillway is also utilized as a principal spillway to pass the above discharge.

North Fork Powder River
Watershed
Fig. 1

Hay Production - Full Water Supply

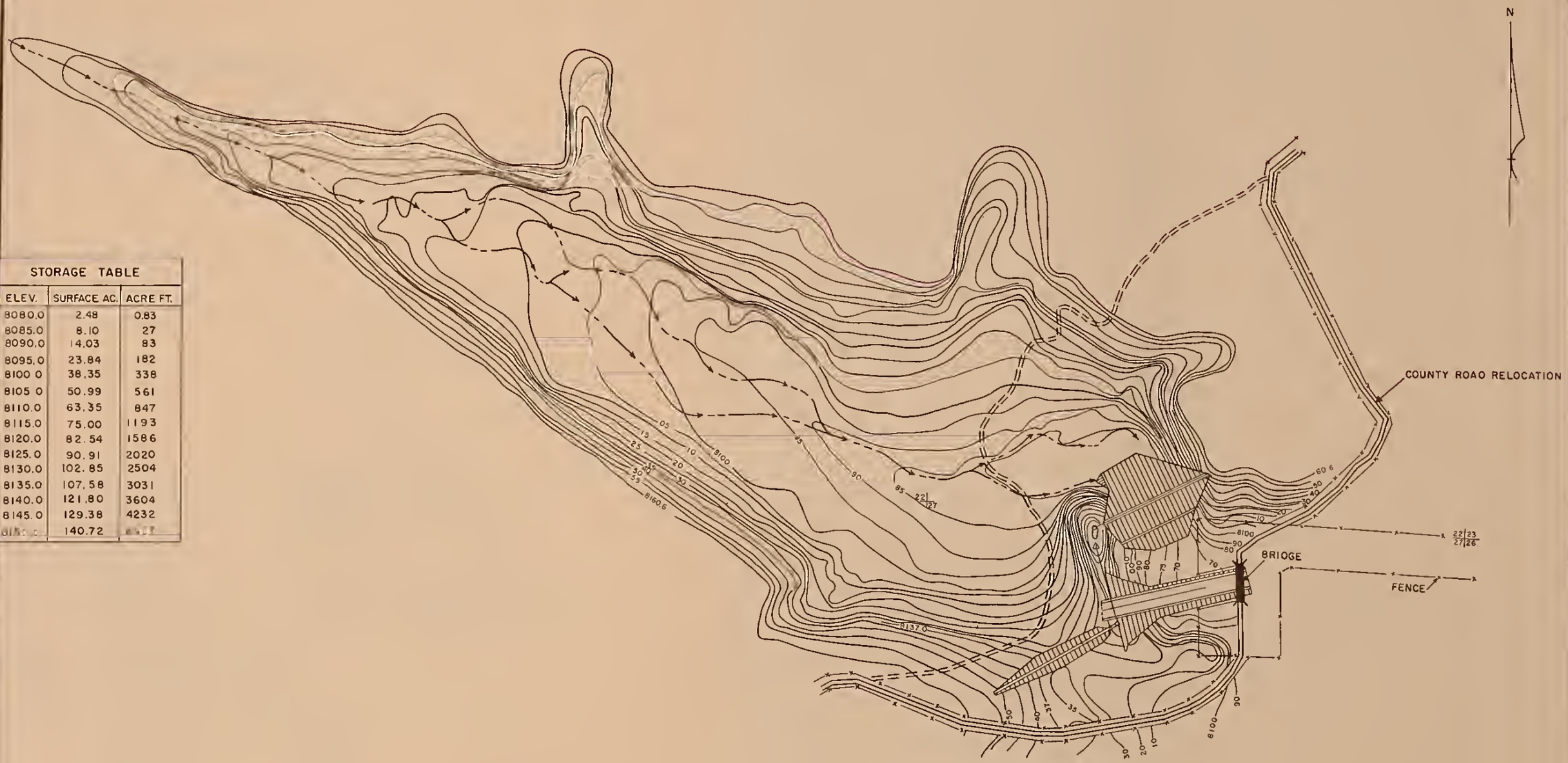
High Producing Native Grass Pasture

North Fork Powder River
Watershed
Fig. 2

Dull Knife Dam

Dull Knife Reservoir Basin

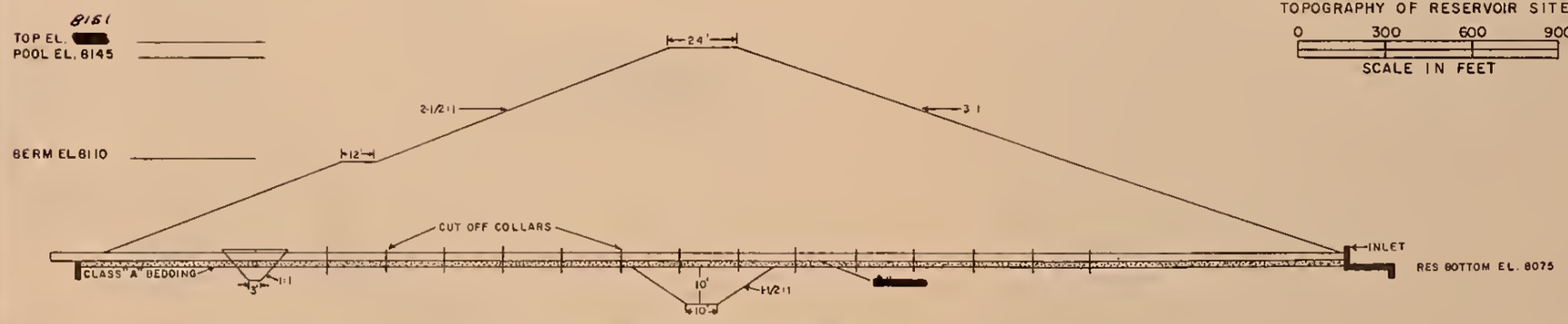
STORAGE TABLE		
ELEV.	SURFACE AC.	ACRE FT.
8080.0	2.48	0.83
8085.0	8.10	27
8090.0	14.03	83
8095.0	23.84	182
8100 0	38.35	338
8105 0	50.99	561
8110.0	63.35	847
8115.0	75.00	1193
8120.0	82.54	1586
8125.0	90.91	2020
8130.0	102.85	2504
8135.0	107.58	3031
8140.0	121.80	3604
8145.0	129.38	4232
[illegible]	140.72	[illegible]



TOPOGRAPHY OF RESERVOIR SITE

0 300 600 900

SCALE IN FEET



EMBANKMENT SECTION OF DAM ALONG ℄ OF CONDUIT

SCALE 1" = 30'

FIGURE 3

WORK PLAN

NORTH FORK POWDER RIVER WATERSHED

JOHNSON COUNTY, WYOMING

DULLKNIFE SITE

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

	Date		
Designed		Approved by	
Drawn	2-28-63	Title	
Traced		Title	
Checked		Sheet No. of	Drawing No. 5, P-19,152

WYOMING PORTION
OF
POWDER RIVER BASIN
AND
NORTH FORK OF THE
POWDER RIVER WATERSHED

U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

PROJECT MAP
NORTH FORK POWDER RIVER WATERSHED
WYOMING

FIGURE 4

LEGEND

- WATERSHED BOUNDARY
- NATIONAL FOREST BOUNDARY
- DRAINAGE
- EXISTING DITCH OR CANAL
- HIGHWAY
- COUNTY ROAD
- DRAINAGE AREA CONTROLLED BY STRUCTURE
- AREA BENEFITED

PROJECT MEASURES

- 1 — IRRIGATION STORAGE STRUCTURE AND NUMBER

THIS WATERSHED IS LOCATED AT APPROXIMATELY:
LATITUDE — 43° 49' NORTH
LONGITUDE — 106° 40' WEST

USDA SCS LINCOLN, NEBR. 1963

5,P-19,150